Signal Processing, Statistical and Learning Machine Techniques for Edge Detection

Dr. Manish Kumar Saini, Deepak Sindhu
Department of Electrical Engineering
Deenbandhu Chhotu Ram University of Science and Technology, Murthal, Sonepat, Haryana, India
E-mail ID: - deepak.sindhu60@gmail.com

***Abstract*-A review of published articles on edge detection is given in this paper. It includes some definitions and different methods of edge detection in different classes. The relation between different classes is given in this review and also gives some calculations about their performance and application. The edge detection methods are the combination of image differentiation, image smoothing and a post processing for edge labelling. A filter is used for image smoothing, due to which noise is reduced, numerical calculation is regularized, and to improve the accuracy and the reliability, it provide a parametric representation that works as mathematical microscope, that will examine it in different scales. To represent the strength and position of edges and their orientation, the image differentiation gives information of intensity transition in the image. To inhibit the false edges, produce a uniform contour of objects, and associate the expanded ones, the edge labelling calls for post processing.**

***Index Terms*- Edge detection, image processing, image differentiation.**

I. Introduction

In computer vision and image processing interpretation of image contents is the main objective. An image contains valuable information such as size, shape, orientation and colour of an image. The main task is to differentiating object from their background. Edge detection is widely used in many applications such as recognition, restoration, morphing, image enhancement, and etc. There are many discontinuities in an image and they are corresponds to: in orientation of surface, in depth, changes in illumination of scene. The process of detection of location and presence of edges in an image is known as edge detection. Generally, an edge detection method can be divided into three stages. Reduction of noise is the first stage. Image noise is reduced to get better performance of edge detection. A low pass filter is used in reducing the noise because additive noise is normally a high frequency signal. However, edges are also high frequency signal so that they can be removed at the same time. To get the best difference between noise reduction and edge information preservation a parameter is commonly used. A high pass filter is commonly used to find edges in the second stage. To identify the genuine edges a localization process is used in the last stage.

Part of an image that consists of substantial changes is called edge. In this paper, a review is discussed of recent two decades on edge detection, significant work, including background, categories and evaluation. Many edge detection methods are present and they are identifying step, vertical, corner and horizontal edges. Noise, density of edges, lighting conditions and objects of similar intensities are the main factors on which the quality of detected edges are dependent. And by changing the value of threshold and by adjusting different parameters these problems can be solved.

Introduction is discussed in I section. Different methods of edge detection are discussed in different categories and also their relationships among them are discussed in II section. Conclusion and the reviewed work are discussed in III section.

II. Related Work

A. Classical Methods

Methods developed by Sobel in 1970 [24], Robert in 1965 [25], and Prewitt [26] are the classical methods. These methods are simply based on a discrete differential operator and don’t use any smoothing filter. These methods are very sensitive to noise because they have no smoothing filter and also they are inaccurate. In classical methods the Sobel operator is the most common operator. 2D spatial gradient convolution is used by the Sobel operator. Convolution masks are used to calculate the gradient, and then find out the pixels gradient. In the end, thresholding of gradient magnitude is done. Sobel operator is an effective and simple technique, but sensitive to noise. In some applications where detection of the outmost contour of an image is required this operator is not suitable. Independent smoothing module is not much beneficial in classical methods; an average over the image is calculated to remove this drawback.

In [1] authors use a difference of boxes to detect edges in his algorithm which uses neighbourhoods of different dimensions and orientations. The neighbourhoods have size related to power of two and have square shape. The difference of the mean intensity values gives the output value of the operator. They choose the ideal operator and to find the ideal operator size is to find the largest one which originates a significant decrease in output value when compared with output value of smaller operator.

B. Gaussian Methods

The most commonly used filters in image processing are Gaussian filters and sometime used as detectors for edge detection. In human vision system it plays a vital role. Some properties of the Gaussian function and some physiological observations are used to develop Gaussian based operator.

DOI: 03.LSCS.2013.3.27

Marr and Hildreth [2] [3] give an edge detector which is based on Gaussian filter. After Canny detector, this method is widely used. In their method they discussed on the variation of image intensity at different levels. A single filter cannot be optimal for all levels, so they require smoothing filters of different scales. A 2D Gaussian function is defined as the smoothing operator. To achieve this, Marr and Hildreth use Laplacian of Gaussian (LOG) function as filter. LOG is a filter having no information about the orientation and it is a scalar estimation of the second derivative. It can't detect edge where intensity function of an image changes in nonlinear manner along an edge, at curves, and at corners where the filter breaks down.

Later, in 80s, Canny [4] [5] give the standard algorithm of edge detection which is better than many of the recent algorithms. He saw that the edge detection is an optimization problem in regards to regularization in image smoothing. Good detection, response to a single edge, and good localization are the three criteria for any edge detector. By maximizing the product of two factors i.e., good localization and detection, an optimal filter is developed. The optimal filter developed was a complicated exponential function, which is well estimated by first derivative of the Gaussian function. This states that the Gaussian function as the smoothing operator followed by the first derivative operator. Canny uses two filters interpreting derivatives on the vertical and horizontal directions in 2D images where image is affected by the white noise. They can break down the 2D Gaussian function into two 1D filters. It searches for local maxima over the first derivative of the filtered image.

C. Multi resolution Methods

In [6], Schunck gives an algorithm in which Gaussian filters are used for the detection of edges at different scales. Schunck's uses initial steps which are based on Canny's method. The initial step in this method is convolving an image with a Gaussian function. After that for each point in the ensuing data array, gradient magnitude and gradient angle are calculated. Then with the help of non maxima suppression (NMS), the gradient ridges in the results of the convolution are reduced. In the next step, the edge map is developed from the reduced gradient magnitudes. The gradient magnitude data will contain large ridges corresponding to the major edges in the image.

For 1D signal, the property of zero crossings across scales was studied by Witkin [7]. He presented zero- crossings of second derivatives versus scales, and these zero crossings is given by Gaussian function of a smoothed signal in a range of scales. This representation which shows the location of a zero-crossing at all scales starting from the smallest scale to the scale at which it disappears is called as the scale-space representation of a signal. Study of edge detection as a function of scale is given by this representation and guided towards the algorithms that are good for edge detection where edges are combined.

To find edge contours William and Shah [8] formulated a new scheme using multiple scales. They used the information, obtained from the movement of edge points reduced with a Gaussian operator of different sizes, to find out the relation between edge points detected at different scales. By following the lead of Canny, to find gradient magnitude and direction, they employ a gradient of Gaussian operator and along with that to determine ridges in the gradient map they use non-maxima suppression (NMS).

D. Non linear Methods

In this section, discussion of non linear methods for better functioning of edge detectors is done. As the researchers found out the relation between the solution to the heat equation in physics and the images convolved with a Gaussian filter for a smoothing purpose, this led to the development of non linear methods based on the Gaussian filter. Perona and Malik [9] offered a scale space representation of an image based on anisotropic diffusion in order to get rid of this problem. As far as mathematical view is concerned, this proposition requires nonlinear partial differential equations instead of linear heat equation. The main idea behind this is to allow space variant blurring. This can be obtained if the diffusion coefficient is made a function of space and scale in the heat equation. Its objective is to keep the boundaries sharp and smooth within a region. This whole process can be seen as a combination of forward and backward diffusion processes.

Z. Guo et al. [17] present a technique which comprises of PM equation with heat equation. Image segmentation, image enhancement, edge detection, and noise removal are provided by Perona-Malik (PM) equation. And with the help of edge indicator as a variable exponent, the diffusion mode is controlled due to which PM diffusion and Gaussian smoothing is alternated according with the image feature.

E. Wavelet Based Methods

As it is discussed earlier, the accuracy and reliability of edge detection increases by analysing an image at different scales. Analysis from a rough to a fine shape is enabled by zooming procedure on localized signal structures, like edges. Discrimination of edges versus textures is simplified by the advancing between scales. Due to this ability edge detection in different applications, wavelet transform is beneficial. Compact representations of images are provided by wavelet based multi resolution expansions having regions of low contrast separated by high contrast edges. Estimation on contrast value by using wavelets for edges on the basis of space varying in a global or local manner as per need is done [10]. While talking about image processing, wavelet transform takes the entire rows and columns of image intensity function, sum over them and mother wavelet function with scaled and shifted version is used for multiplication. Coefficients that are function of the scale and shifts are given by the above discussion. Heric and Zazula [11] use Haar wavelet transform in their edge detection algorithm. Because of its compact, orthogonal and without spatial shifting in transform space, they use Haar wavelet as the basic wavelet function. The intensity magnitude changes between next intervals on a

time scale plane is presented by applying wavelet transform. To extract edges Shih and Tseng [12] combined a wavelet based multi-scale edge tracking and a gradient-based edge detection gradient based edge detection. Edges are detected from the finest scale gradient images from the proposed contextual filter and then, the detected edges on the multi-scale gradient images are refined by the edge tracker.

F. Line Edge Detectors

An algorithm based on polynomial fitting is proposed by Haralick [13]. A linear combination of discrete bases of Tchebychev's polynomial is used to fit the image having order less than or equal to three. The direction of the lines occurring at pixels having zero crossings of the first directional derivative should be taken along the maximization of the second directional derivative.

C. Akinlar et al. [18] present an algorithm Edge Drawing Parameters Free (EDPF). This algorithm use parameter free edge segment detector and the connected set of edge segments produced by this. In proposed algorithm edge segments are computed in a given image using EDPF, and thereafter converted into line segments. Line segments which are detected are converted into circular arcs; two heuristic algorithms are used to join the areas which further used to detect near-circular ellipses and candidate circles.

C.Gopal, and C.Akinlar [19] present a novel edge segment detection algorithm which first spot sparse points along rows and column called anchors and then joins there anchors with the help of edge tracing procedure called Edge Drawing (ED). ED is a technique which gives high quality edge maps and runs up to 10% faster than the Canny edge detector.

G. Statistical Methods

Konishi [14] develop the edge detection as a statistical inference. Unlike other model based methods for edge detection, this statistical edge detection is data driven. Pre-segmented images are used to instruct probability distribution of edge detection filters. Ratio test on the filter responses specifies a discrimination task which is used in formulation of edge detection. This approach conveys the importance of modelling the image background. Conditional probability distributions are represented by them non-parametrically and two different data sets of images are illustrated. Joint distribution is used to combine multiple edges defined over multiple scales and obtain an optimal combination. While talking about the effectiveness of these results, they show better performance in the images containing background jumble than canny edge detector.

T. Qui et al. [20] presents an auto adaptive edge detection algorithm for detecting edges in a flame and fire images. The proposed technique determines the fire evaluation, and determination of flame and fire parameters. The proposed technique results are much better than the traditional edge detection.

F. Baselice et al. [21] present a novel statistical edge detection technique to obtain a map of man-made structure edges from the SAR images. The proposed technique using jointly both the amplitudes and inferometric phases of two complex SAR image based on hypothesis that information related to building edges can be retrieved into image or to domain. The proposed technique is an estimation based technique exploiting the random field.

H. Machine Learning Based Methods

A fuzzy neural network is proposed by Lu et al. [15] for edge detection and enhancement by eliminating false edges caused by noise and by recovering missing edges. The algorithm consists of three stages given as; edge detection by a three layer feed forward fuzzy neural network, adaptive fuzzification by fuzzifying the input patterns, and edge enhancement by a modified Hopfield neural network. To train a fuzzy neural network, the typical sample patterns were fuzzified and then applied. The edge elements with eight orientations are determined by the trained neural network. For further processing, pixels having high edge membership were traced

C.Lopez-Moline et al. [22] give a method in which conversion of a gradient image to a fuzzy edge image, and for this conversion different parametric membership functions are considered. And for determining the values of parameters a histogram-based scheme is introduced. Canny method is applied on the functions for edge detection.

T.Chaira [23] presents an enhancement and detection algorithm based on intuitionistic fuzzy set theory and Canny edge detector respectively of medical image. In this technique, image is first converted to intuitionistic fuzzy image and to obtain a proper value of the parameter in membership and non-membership function intuitionistic fuzzy entropy is used. And after this, Canny edge detector is used for segmentation.

Optimization technique for edge detection based on genetic algorithm (GA) is given by Bhandarkar et al. [16]. A minimum cost edge configuration is the main problem of edge detection. 2D genome having fitness values inversely proportional to their costs is the edge configuration, and meantime, crossover and mutation, two basic GA operators were described in the context of the 2D genomes. Rapid convergence is showed by the local edge structure which is given by the mutation operator.

III. Conclusion

In general, specific environmental conditions are the main factor for choosing a suitable method. As there are many methods for edge detection but all have advantages and dis-advantages, so as per requirement best algorithm is selected so that errors are minimum. The results of edge detection techniques using Gaussian filter are not satisfactory. Problems like false edges, vanishing edges, and edge displacement are occurred in linear methods which are associated with Gaussian filtering. Non linear methods demonstrate important advancement in localization and edge detection over linear methods.

DOI: 03.LSCS.2013.3.27

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DOI: 03.LSCS.2013.3.27